

Waste Heat Recovery Steam Generator in Sponge Iron Plant

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Abstract—Power has become an essential commodity all over world today, with rapid development in infrastructure and other aspects, Power has become the most sought out commodity. Globally conventional fuels are going to be exhausted. World wide all resource & development organizations are focusing on non-conventional energy & effective utilization of conventional energies. In sponge iron plant, rotary kiln is used to manufacture iron billets from combustion of coal and iron ore. Waste flue gas emitted from the rotary kiln has a temperature of 700°C and above. Gas cooler is required to cool the gas to the acceptable level. Our project is focused on installation of a WHRSG instead of gas cooler for both gas cooling by heat recovery & steam generation. Thus the whole plant efficiency is improved by effective utilization of waste heat energy and eliminating the power which is consumed by gas cooler.

Keywords—Conventional Energies, Conventional Fuel, Flue Gas Cooler, Non-Conventional Fuels, Sponge Iron Plant, Steam Generator, Waste Heat Recovery

Abbreviations—Bureau of Energy Efficiency (BEE), Clean Development Mechanism (CDM), Electro Static Precipitator (ESP), National Institute of Technology (NIT), Waste Heat Recovery Steam Generator (WHRSG)

I. INTRODUCTION

POWER has become an essential commodity all over the world today, with rapid development in infrastructure and other aspects. Power has become the most sought out commodity.

1.1. Intention

Many countries are looking for alternative energy sources and they are trying to generate power from renewable energy sources too. In a scenario like this we should do our best to utilize the existing power resource to its fullest extent.

This project is intended to portray the potential of generating power from an already existing resource like a sponge iron plant.

1.2. General Energy Scenario

Globally present conventional fuels are exhausted; we are focusing on non-conventional energy & effective utilization of present conventional energies to manage power requirement.

In India industrial sector consumes 42% of total conventional energy. So energy conservation in industry will give more effective than production of such energies.

In our nation, we are focused on energy conservation in industrial sector because of more power is required to run our

most of industry like cement plant, iron plant & sugar plant etc.

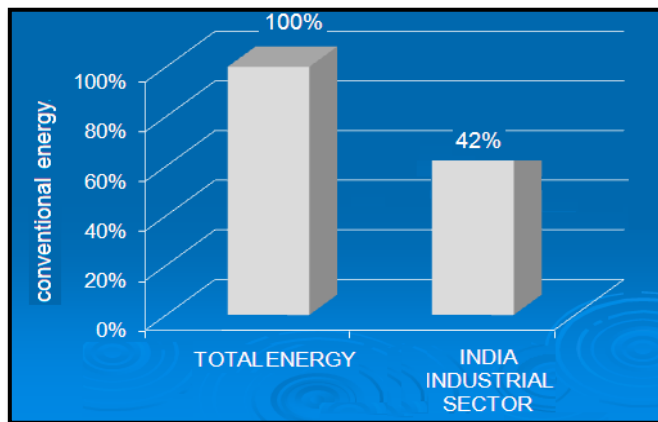


Figure 1 – General Energy Scenario

1.3. Energy Intensity in Steel Industry

Energy intensity in Indian industries is high when compared to other developed countries like Japan, Germany & USA etc., because of poor technology are used in such industries.

Special thrust needs to be laid on more energy consumed in sponge iron plant, which is more heat energy is required to melt the iron ore to produce sponge iron.

50% of the total heat energy produced only utilized for steel production. Remaining 50% of gas is exhausted as a waste heat which has lot of sensible heat.

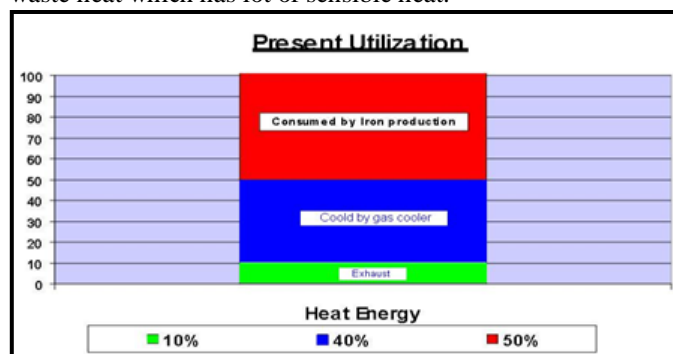


Figure 2 – Energy Intensity in Iron Plant
(50% of total produced heat only used)

II. EXPERT REVIEW

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Waste gas from the rotary kiln of the sponge iron plant exits at a temperature around 900° C. This gas has a lot of sensible heat and can be used for energy integration.

Summary report of “Investigation for CDM project of waste heat recovery based captive power plant in sponge iron plants of Orissa, India”

A lot of sponge iron manufacturers with rotary kiln are operating in India, and waste heat gas is disposed to the air. Electric generation utilizing this gas is very beneficial to improve.

Anil Kumar Prasad, Department of Mechanical Engineering, NIT

A tremendous amount of heat is generated in the coal based sponge iron plant and a significant part of this heat associated with the waste gas can be unutilized

Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India

Excessive utilization of thermal and electrical energy also impacts the regional Energy balance and has a direct impact on the local power utility; it also impedes the improvement of productivity.

III. WASTE HEAT UTILIZING BY STEAM GENERATOR IN SPONGE IRON PLANT

3.1. Possibility

This project is intended to portray the potential of generating power from an already existing resource like a Sponge Iron Plant and waste gas with lot of sensible heat disposed to the atmosphere [Chattopadhyay, 2003].

In this sponge iron plant, a rotary kiln is used to manufacture iron billets by melting iron ore by coal. In this case lot of heat energy is required for iron plant.

Waste flue gas emitted from this rotary kiln will be of temperature around 700° C and above. In temperature 700° C

thus eliminating the need for an external fuel for super heat steam generation.

3.2. Energy Conservation in Steel Industry

50% of total heat generated is exhausted as waste heat with lot of sensible heat with around 700° C temperature.

35 KW power is required for gas cooler which is used to cool the gas by mixing of air with gas to fulfil the thermal pollution board control norms level.

Above waste energy is conserved by WHRSG installation and eliminate power required for gas cooler. The generated steam can be used for steam turbine to generate power.

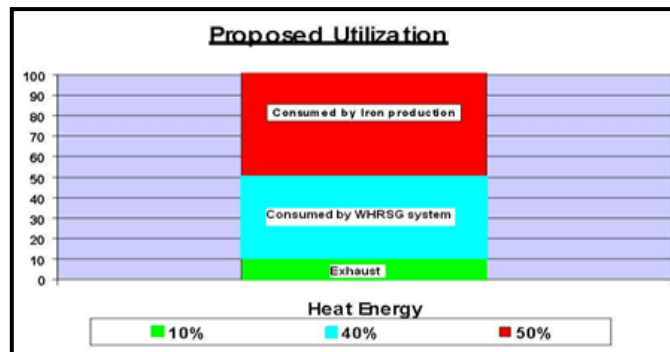


Figure 3 – Energy Conservation in Iron Plant
(90% of total produced heat can use)

3.3. Project Proposal

Normally an external fuel is used in Boilers for producing flue gas with temperature about 850° C. This flue gas is the one which is used to generate steam, which in turn produces power [Rajput, 2004; Nag, 2006].

It is proposed in this project to effectively utilize the waste flue gas generated from rotary kilns to produce electricity, because this waste flue gas generated from producing iron will already be of temperature 700° C thus eliminating the need for an external fuel.

3.4. Benefits

- Reduces massively the need for external fuel like coal for producing the same amount of electricity. In addition to fuel handling system, fuel feeding system and combustion chamber with fan and blowers are eliminated.
- Effective utilization of energy resources maximum of 90% in the sponge iron plant.
- Eliminates power required for gas cooler and the same power is used for WHRSG auxiliaries like boiler feed pump.

3.5. New Proposed Project

This project is focused on installation of a WHRSG instead of gas cooler for gas cooling by heat recovery and steam generation for better energy conservation in sponge iron plant and improves thermal efficiency [Arora & Domkumpwar, 1975].

Thus the whole plant efficiency is improved by effective utilization of waste heat energy and eliminating the power which is consumed by gas cooler.

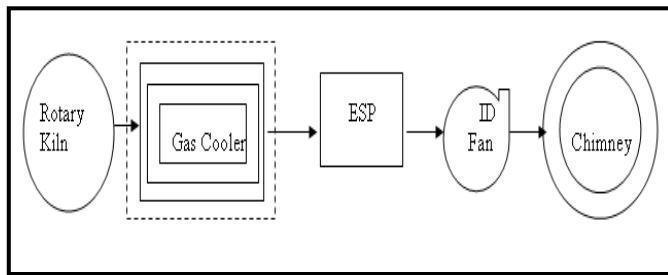


Figure 4 – Existing Plant with Gas Cooler

Gas cooler is required to cool the hot flue gas as required with thermal pollution control board norms.

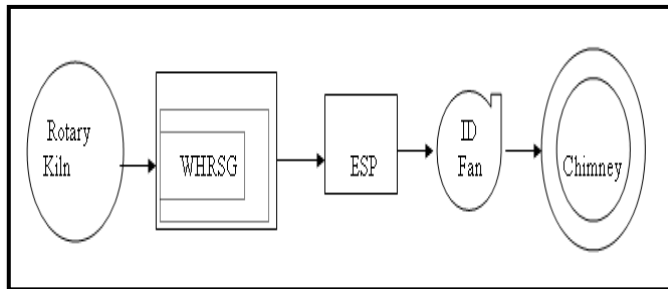


Figure 5 – New Proposal Plant with WHRSG

WHRSG is used instead of gas cooler for gas cooling by heat recovery and steam generation.

3.6. Boiler Design Consideration

The following are the boiler design considerations [Reay & Span, 1979; Brad Bucker, 2002; Ganapathy, 1979].

Flue Gas Rate 18,522 Kg/hr = (14,000 Nm³/hr)

Flue Gas Inlet Temperature = 700 °C

Steam Pressure at the outlet of MSSV = 40 bar

Steam Temp at the outlet of MSSV = 300 ±5°C

Flue Gas Temperature at Economiser outlet = 160 °C

Water Temperature at Economiser Inlet = 105 °C

Pinch point at Evaporator (°C) Pp = 41

Economiser water Approach (°C) Ap = 20

Blow down in % of steam Outlet = 2.5

Pressure Drop in Super heater = 3 bar

Pressure Drop in Economiser = 1 bar

3.7. Boiler Capacity Calculation

The following worksheet gives the boiler capacity calculation [Sachdeva, 2003; Kothandaramar & Subramanyan, 2010; Khurmi, 1984].

* Heat available to Evaporator and Super Heater

$$* H(\text{available}) = mg \cdot (h_{gi} - h_p) = 9918234.65 \text{ kJ/hr}$$

$$* H(\text{net heat}) = H_{av} / (1 + SL/100) = 9676326.49 \text{ kJ/hr}$$

* Heat Required by steam flow (To Pinch Point)

$$* H(\text{reqd}) = ms \cdot (h_{so} - h_{liq}) + (ms + ms \cdot SL/100) (h_{liq} - h_{wo})$$

Since, H(net) is equal to H(reqd)

$$* ms = \frac{H(\text{net})}{[(h_{so} - h_{liq}) + (1 + SL/100) (h_{liq} - h_{wo})]} = 4960.78 \text{ kg/hr}$$

$$\text{Total Steam Generation (Ms)} = 5000 \text{ kg/hr}$$

3.8. Boiler Heat Balance Calculation

The following worksheet gives the boiler heat balance calculation [Sachdeva, 2003; Kothandaramar & Subramanyan, 2010; Khurmi, 1984].

* Superheater Heat Required

* Q_{sh} = $M_s \cdot (h_{so} - h_{viq})$ = **815750** kJ/hr

* Gas Enthalpy at Super heater outlet

* $h_g(sho)$ = $[h_{gi} - (Q_{sh}/m_g)]$ = **823.26** kJ/kg

* Temperature of gas after SH section (T_{gevp}) = **668** °C

* **The Evaporator Duty (Q_{evp})**

* Q_{evp} = $M_s \cdot (h_{vap} - h_{liq}) + M_s \cdot (1 + SL/100) \cdot (h_{liq} - h_{wo})$ = **8937087.5** kJ/hr

* **The Steam Generated in the Evaporator Coil (M_{evp})**

* M_{evp} = $Q_{evp} / (h_{vap} - h_{li})$ = 5006.63 kg/hr

* **The Economiser Duty (Q_{eco})**

* Q_{eco} = $M_s \cdot (h_{wo} - h_{wi})$ = **2939802.5** kJ/hr

* **Gas Enthalpy at the outlet of Economiser Coil (h_{go})**

* h_{go} = $h_p - Q_{eco}/m_g$ = **173.1** kJ/kg

* Temperature of gas after Economiser = **160** °C

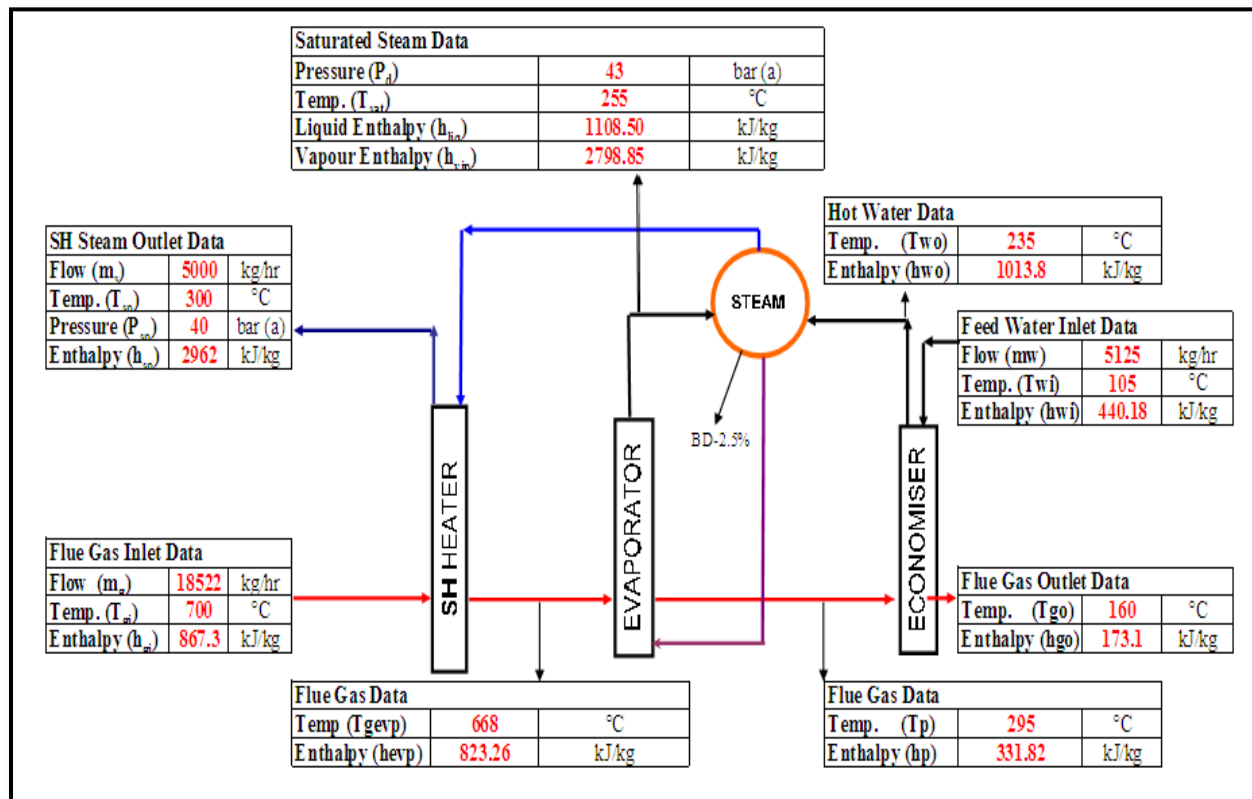


Figure 6 – WHRSG Heat Duty Diagram

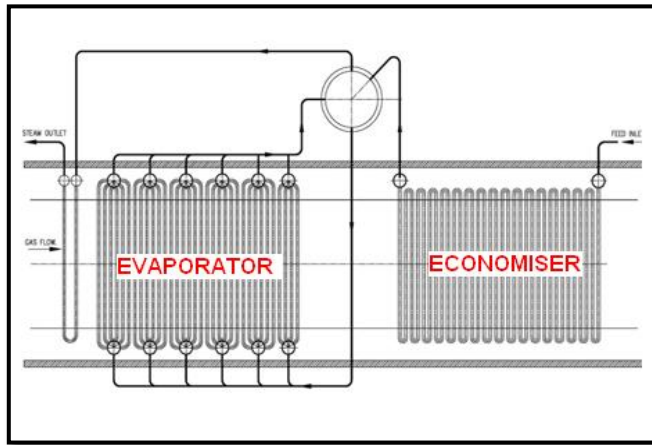


Figure 7 – WHRSG General Arrangement [ASME; BS 1113:1999; Indian Boiler Regulations 1950 Code Book]

IV. RESULTS

4.1. Merits

- Effective utilization of energy resources in the Sponge Iron Plant maximum of 90%
- Eliminate power required for gas cooler which is compensated the power required for WHRSG auxiliary equipment power like boiler feed pump etc.
- Increase overall plant Efficiency and thermal efficiency of rotary kiln in sponge iron plant.

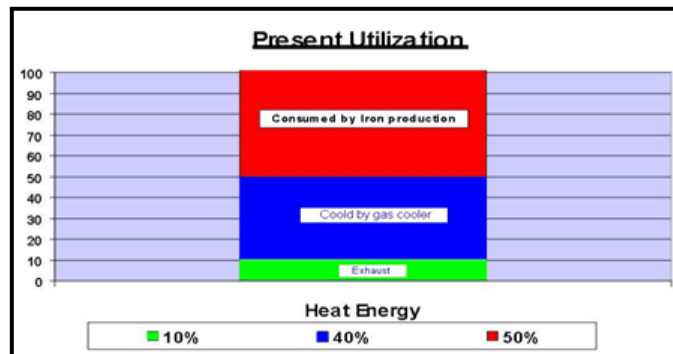
4.2. Compare WHRSG with Fired Boiler

Table1 – Steam Generation Cost Comparison [M/s Vecons Design Data Book, M/s. BHEL Design Data Book, M/s. Thermax Design Data Book]

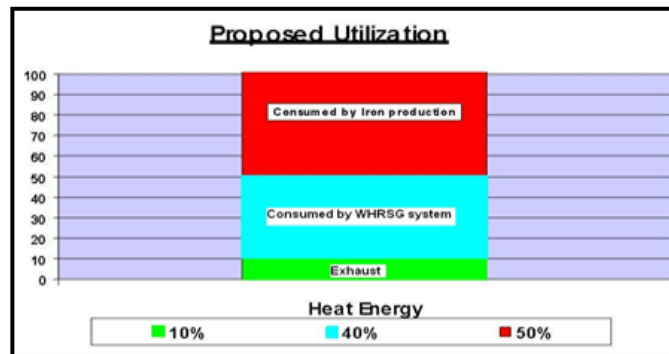
	UNITS	FBCB	WHRSG
Capacity	kg/hr	5000	5000
Hours		24	24
N0. Of working days per annum		330	330
Annual Steam Generation	kg/hr	39600000	39600000
Fixed Cost			
Boiler cost	Rupees	22500000	18000000
O & M (1.5% of project cost)	Rupees	337500	270000
Over heads (1.5% of project cost)	Rupees	337500	270000
Interest (10% of project cost)	Rupees	2250000	1800000
Depreciation (5% of project cost)	Rupees	1125000	900000
Total fixed cost without depreciation	Rupees	2925000	2340000
Total fixed cost with depreciation	Rupees	4050000	3240000
Variable Cost			
Fuel used for FBC boiler: Indian coal			
GCV of fuel: 3800 kcal / kg			
Boiler efficiency: 83±1%			
Fuel requirement per hour	kg/hr	963.000	-
Fuel requirement per annum	kg/hr	7626960.000	-
Fuel cost per kg	Rupees	2.5	-
Total fuel cost per year	Rupees	19067400	-
Variable cost	Rupees	19067400	-
Steam Generation Cost			
Steam Generation Cost = (Fixed Cost + Variable Cost) / Steam generation per annum			
Steam generation cost per kg without depreciation	Rupees	0.555	0.059
Steam generation cost per kg with depreciation	Rupees	0.584	0.082

Table 2 – Highlights of WHRSG [M/s Vecons Design Data Book]

Description	Unit	5 TPH FBCB	5 TPH WHRSG
Fuel storage system	Lakhs	7.125	Nil
Fuel feeding system	Lakhs	1.89	Nil
FD / PA system including air box	Lakhs	16	Nil
ESP & mild steel chimney	Lakhs	57.5	Nil
Power consumption cot / year	Lakhs	35.6	Negligible
Total boiler cost	Lakhs	225	180
Cost of per kg of steam			
Annual steam generation	Tons	39600	39600
Fixed cost	Lakhs	40.5	32.4
Variable cost	Lakhs	191	Nil
Cost of per kg of steam	Paise	58.4	8.2



Existing Energy Intensity
(50% of total produced heat only used)



Proposed Energy Conservation
(90% of total produced heat can use)

Figure 8 – Merits Graph (Energy Utilization in Sponge Iron Plant)

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V. CONCLUSION

Effective utilization is better than production. Thus the energy is available at free of cost without fuel fired. Production cost of heat energy includes cost of fuel, fuel fired equipments and its power.

By effectively utilising the heat energy by WHRSG we would be able to save approximately 50.2 paise per kg of steam generation as compared with fired boiler steam generation which is required fuel, fuel feeding system, combustion chamber, fans, blowers, and auxiliary power 150KW etc.

Annual savings will come around 198.79 lakhs which is more than the boiler cost approximate 180 lakhs. So the pay back period will one year. Normal boiler life is minimum 10 years.